

CLAIMS:

1. A method for forming graded junction regions operatively adjacent a transistor gate of CMOS circuitry, the method comprising the following steps:

providing a semiconductor material wafer;

defining a PMOS region and an NMOS region of the wafer;

providing a PMOS transistor gate over the PMOS region and providing an NMOS transistor gate over the NMOS region, the transistor gates having opposing lateral sidewalls;

providing sidewall spacers adjacent the sidewalls of the transistor gates, the sidewall spacers having a lateral thickness and comprising a sidewall spacer material;

providing a masking layer over the PMOS region;

after providing the masking layer over the PMOS region, and after providing the sidewall spacers adjacent the NMOS transistor gate, implanting an n-type conductivity-enhancing dopant into the semiconductor wafer to form electrically conductive NMOS source/drain regions within the semiconductor material operatively adjacent the NMOS transistor gate;

after forming the electrically conductive NMOS source/drain regions, etching the sidewall spacer material adjacent the NMOS transistor gate to remove only a portion of said spacer material and to thereby decrease the lateral thickness of the sidewall spacers adjacent the NMOS transistor gate; and

after decreasing the lateral thickness of the sidewall spacers adjacent the NMOS transistor gate, implanting a p-type conductivity-enhancing dopant into the semiconductor material to form halo regions operatively adjacent the NMOS source/drain regions.

2. The method of claim 1 further comprising, after providing transistor gates over the PMOS region and NMOS region, and prior to providing sidewall spacers adjacent the sidewalls of the transistor gates, forming NMOS LDD regions operatively adjacent the NMOS transistor gate.

1 3. The method of claim 1 further comprising:

2 after forming the electrically conductive NMOS source/drain
3 regions, and prior to etching the sidewall spacer material adjacent the
4 NMOS transistor gate, stripping the masking layer from over the PMOS
5 region;

6 etching the sidewall spacer material adjacent the PMOS transistor
7 gate to decrease the lateral thickness of the sidewall spacers adjacent
8 the PMOS transistor gate; and

9 after decreasing the lateral thickness of the sidewall spacers
10 adjacent the NMOS transistor gate and the PMOS transistor gate,
11 blanket implanting the p-type conductivity-enhancing dopant into the
12 semiconductor material of both the PMOS region and the NMOS region
13 to form halo regions operatively adjacent the NMOS transistor gate and
14 to form PMOS LDD regions operatively adjacent the PMOS transistor
15 gate.

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17 4. The method of claim 3 further comprising, prior to
18 decreasing the lateral thickness of the sidewall spacers adjacent the
19 PMOS transistor gate and subsequent to stripping the masking layer
20 from over the PMOS region, forming electrically conductive PMOS
21 source/drain regions within the semiconductor material operatively
22 adjacent the PMOS transistor gate.

1 5. The method of claim 1 further comprising, prior to
2 providing the masking layer over the PMOS region, forming PMOS LDD
3 regions operatively adjacent the PMOS transistor gate.
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5 6. The method of claim 1 wherein the semiconductor material
6 wafer comprises an overall planar global configuration, the planar global
7 configuration establishing a virtual planar top surface and an axis
8 normal to the virtual planar top surface, and wherein the p-type
9 conductivity-enhancing dopant is implanted at an angle other than
10 parallel to the axis normal to the virtual planar top surface.
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1 7. The method of claim 1 further comprising:

2 prior to providing the masking layer over the PMOS region,
3 forming PMOS LDD regions operatively adjacent the PMOS transistor
4 gate;

5 after forming the electrically conductive NMOS source/drain
6 regions, and prior to etching the sidewall spacer material adjacent the
7 NMOS transistor gate, stripping the masking layer from over the PMOS
8 region;

9 etching the sidewall spacer material adjacent the PMOS transistor
10 gate to decrease the lateral thickness of the sidewall spacers adjacent
11 the PMOS transistor gate; and

12 after decreasing the lateral thickness of the sidewall spacers
13 adjacent the NMOS transistor gate and the PMOS transistor gate,
14 blanket implanting the p-type conductivity-enhancing dopant into the
15 semiconductor material of both the PMOS region and the NMOS region
16 to form halo regions operatively adjacent the NMOS transistor gate and
17 to enhance the conductivity of the PMOS LDD regions.

1 8. The method of claim 1 wherein the semiconductor material
2 wafer comprises an overall planar global configuration, the planar global
3 configuration establishing a virtual planar top surface and an axis
4 normal to the virtual planar top surface, and further comprising:

5 after forming the electrically conductive NMOS source/drain
6 regions, and prior to etching the sidewall spacer material adjacent the
7 NMOS transistor gate, stripping the masking layer from over the PMOS
8 region;

9 etching the sidewall spacer material adjacent the PMOS transistor
10 gate to remove only a portion of said spacer material and to thereby
11 decrease the lateral thickness of the sidewall spacers adjacent the PMOS
12 transistor gate; and

13 after decreasing the lateral thickness of the sidewall spacers
14 adjacent the NMOS transistor gate and the PMOS transistor gate,
15 blanket implanting the p-type conductivity-enhancing dopant at an angle
16 other than parallel to the axis normal to the virtual planar top surface
17 to form NMOS halo regions operatively adjacent the NMOS transistor
18 gate and to form PMOS LDD regions operatively adjacent the PMOS
19 transistor gate.

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21 9. The method of claim 1 wherein the portion of spacer
22 material removed from the sidewall spacers constitutes no more than
23 about 90% of the lateral thickness of the sidewall spacers adjacent the
24 NMOS transistor gate.

1 10. The method of claim 1 wherein the sidewalls of the
2 transistor gates comprise polysilicon, the method further comprising:

3 prior to providing sidewall spacers adjacent the sidewalls, oxidizing
4 the polysilicon of the sidewalls.
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6 11. The method of claim 10 further comprising, prior to
7 providing sidewall spacers adjacent the sidewalls of the NMOS transistor
8 gate, forming NMOS LDD regions operatively adjacent the NMOS
9 transistor gate.
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11 12. CMOS circuitry comprising at least one transistor formed by
12 the method of claim 1.
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13. A method for forming graded junction regions operatively adjacent a transistor gate, the method comprising the following steps:

providing a semiconductor material wafer;

providing a transistor gate over the semiconductor material wafer, the transistor gate having opposing lateral sidewalls;

providing sidewall spacers adjacent the sidewalls of the transistor gate, the sidewall spacers having a lateral thickness and comprising a sidewall spacer material;

after providing the sidewall spacers, implanting a first conductivity-enhancing dopant into the semiconductor wafer to form electrically conductive source/drain regions within the semiconductor material operatively adjacent the transistor gate;

after forming the electrically conductive source/drain regions, etching the sidewall spacer material to remove only a portion of said spacer material and to thereby decrease the lateral thickness of the sidewall spacers; and

after decreasing the lateral thickness of the sidewall spacers, implanting a second conductivity-enhancing dopant into the semiconductor material to form graded junction regions operatively adjacent the source/drain regions.

1 14. The method of claim 13 wherein the semiconductor material
2 wafer comprises an overall planar global configuration, the planar global
3 configuration establishing a virtual planar top surface and an axis
4 normal to the virtual planar top surface, and wherein the second
5 conductivity-enhancing dopant is implanted at an angle other than
6 parallel to the axis normal to the virtual planar top surface.

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8 15. The method of claim 13 wherein the transistor is a PMOS
9 transistor, the second conductivity-enhancing dopant is a p-type dopant,
10 and the implant of the second conductivity-enhancing dopant forms LDD
11 regions operatively adjacent the PMOS source/drain regions.

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13 16. The method of claim 13 wherein the transistor is a PMOS
14 transistor, the second conductivity-enhancing dopant is an n-type dopant,
15 and the implant of the second conductivity-enhancing dopant forms halo
16 regions operatively adjacent the PMOS source/drain regions.

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18 17. The method of claim 16 wherein the second conductivity-
19 enhancing dopant comprises phosphorus.

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21 18. The method of claim 13 wherein the transistor is an NMOS
22 transistor, the second conductivity-enhancing dopant is a p-type dopant,
23 and the implant of the second conductivity-enhancing dopant forms halo
24 regions operatively adjacent the NMOS source/drain regions.

1 19. The method of claim 18 wherein the second conductivity-
2 enhancing dopant comprises boron.

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4 20. The method of claim 13 wherein the transistor is an NMOS
5 transistor, the second conductivity-enhancing dopant is a n-type dopant,
6 and the implant of the second conductivity-enhancing dopant forms LDD
7 regions operatively adjacent the NMOS source/drain regions.

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9 21. A transistor formed by the method of claim 13.

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11 22. A method for implanting graded junction regions into a
12 peripheral NMOS transistor and source/drain regions into a memory
13 array of NMOS transistors, the method comprising the following steps:

14 providing a semiconductor material wafer;

15 defining a memory array region of the wafer;

16 defining a PMOS region and a peripheral NMOS region of the
17 wafer;

18 providing a PMOS transistor gate over the PMOS region, providing
19 a peripheral NMOS transistor gate over the peripheral NMOS region,
20 and providing an array of memory NMOS transistor gates over the
21 memory array region, the transistor gates having opposing lateral
22 sidewalls;

1 providing sidewall spacers adjacent the sidewalls of the transistor
2 gates, the sidewall spacers having a lateral thickness and comprising a
3 sidewall spacer material;

4 providing a masking layer over the PMOS region and over the
5 memory array region;

6 after providing the masking layer over the PMOS region and the
7 memory array region, and after providing the sidewall spacers adjacent
8 the peripheral NMOS transistor gate, implanting an n-type conductivity-
9 enhancing dopant into the semiconductor wafer to form electrically
10 conductive peripheral NMOS source/drain regions within the
11 semiconductor material operatively adjacent the peripheral NMOS
12 transistor gate;

13 after forming the electrically conductive NMOS source/drain
14 regions, etching the sidewall spacer material adjacent the peripheral
15 NMOS transistor gate to remove only a portion of said spacer material
16 and to thereby decrease the lateral thickness of the sidewall spacers
17 adjacent the peripheral NMOS transistor gate; and

18 after decreasing the lateral thickness of the sidewall spacers
19 adjacent the peripheral NMOS transistor gate, implanting p-type
20 conductivity-enhancing dopant into the semiconductor material to form
21 halo regions operatively adjacent the peripheral NMOS source/drain
22 regions.

1 23. The method of claim 22 further comprising, after providing
2 transistor gates over the peripheral NMOS region and over the memory
3 array region, and prior to providing sidewall spacers adjacent the
4 sidewalls of the transistor gates, providing LDD regions operatively
5 adjacent the peripheral NMOS transistor gate and providing memory
6 gate source/drain regions operatively adjacent the memory NMOS
7 transistor gates.

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9 24. The method of claim 22 further comprising:

10 after forming halo regions operatively adjacent the NMOS
11 source/drain regions, stripping the masking layer from over the PMOS
12 region and providing a masking layer over the peripheral NMOS region;

13 after providing the masking layer over the NMOS region, etching
14 the sidewall spacer material adjacent the PMOS transistor gate to
15 decrease the lateral thickness of the sidewall spacers adjacent the PMOS
16 transistor gate; and

17 after decreasing the lateral thickness of the sidewall spacers
18 adjacent the PMOS transistor gate, implanting n-type conductivity-
19 enhancing dopant into the semiconductor material to form halo regions
20 operatively adjacent the PMOS transistor gate.

1 25. The method of claim 24 further comprising, prior to
2 decreasing the lateral thickness of the sidewall spacers adjacent the
3 PMOS transistor gate and subsequent to stripping the masking layer
4 from over the PMOS region, forming electrically conductive PMOS
5 source/drain regions within the semiconductor material operatively
6 adjacent the PMOS transistor gate.

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8 26. The method of claim 22 further comprising:

9 after forming halo regions operatively adjacent the NMOS
10 source/drain regions, stripping the masking layer from over the PMOS
11 region and providing a masking layer over the peripheral NMOS region;

12 after providing the masking layer over the NMOS region, etching
13 the sidewall spacer material adjacent the PMOS transistor gate to
14 decrease the lateral thickness of the sidewall spacers adjacent the PMOS
15 transistor gate; and

16 after decreasing the lateral thickness of the sidewall spacers
17 adjacent the PMOS transistor gate, implanting p-type conductivity-
18 enhancing dopant into the semiconductor material to form LDD regions
19 operatively adjacent the PMOS transistor gate.

1 27. The method of claim 26 further comprising, prior to
2 decreasing the lateral thickness of the sidewall spacers adjacent the
3 PMOS transistor gate and subsequent to stripping the masking layer
4 from over the PMOS region, forming electrically conductive PMOS
5 source/drain regions within the semiconductor material operatively
6 adjacent the PMOS transistor gate.

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8 28. The method of claim 22 further comprising:

9 after forming the electrically conductive peripheral NMOS
10 source/drain regions, and prior to etching the sidewall spacer material
11 adjacent the peripheral NMOS transistor gate, stripping the masking
12 layer from over the PMOS region;

13 etching the sidewall spacer material adjacent the PMOS transistor
14 gate to decrease the lateral thickness of the sidewall spacers adjacent
15 the PMOS transistor gate; and

16 after decreasing the lateral thickness of the sidewall spacers
17 adjacent the peripheral NMOS transistor gate and the PMOS transistor
18 gate, blanket implanting the p-type conductivity-enhancing dopant into
19 the semiconductor material of both the PMOS region and the NMOS
20 region to form halo regions operatively adjacent the NMOS transistor
21 gate and to form PMOS LDD regions operatively adjacent the PMOS
22 transistor gate.

1 29. The method of claim 28 further comprising, prior to
2 decreasing the lateral thickness of the sidewall spacers adjacent the
3 PMOS transistor gate and subsequent to stripping the masking layer
4 from over the PMOS region, forming electrically conductive PMOS
5 source/drain regions within the semiconductor material operatively
6 adjacent the PMOS transistor gate.

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8 30. A semiconductor wafer comprising a peripheral NMOS and
9 a memory array formed by the method of claim 22.

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11 31. A method for forming graded junction regions operatively
12 adjacent a transistor gate, the method comprising the following steps:

13 providing a semiconductor material wafer;

14 providing a transistor gate over the semiconductor material wafer,
15 the transistor gate having opposing lateral sidewalls;

16 providing sidewall spacers adjacent the sidewalls of the transistor
17 gate, the sidewall spacers having a lateral thickness and comprising a
18 sidewall spacer material;

19 decreasing the lateral thickness of the sidewall spacers by
20 removing only a portion of the sidewall spacers; and

21 after decreasing the lateral thickness of the sidewall spacers,
22 implanting a conductivity-enhancing dopant into the semiconductor
23 material to form graded junction regions operatively adjacent the
24 transistor gate.

1 32. The method of claim 31 wherein the semiconductor material
2 wafer comprises an overall planar global configuration, the planar global
3 configuration establishing a virtual planar top surface and an axis
4 normal to the virtual planar top surface, and wherein the second
5 conductivity-enhancing dopant is implanted at an angle other than
6 parallel to the axis normal to the virtual planar top surface.

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8 33. The method of claim 31 further comprising, after providing
9 the sidewall spacers and prior to decreasing the lateral thickness of the
10 sidewall spacers, providing electrically conductive source/drain regions
11 operatively adjacent the transistor gate.

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13 34. The method of claim 31 further comprising incorporating the
14 transistor gate into a PMOS transistor, wherein the implanted
15 conductivity-enhancing dopant is a p-type dopant, and wherein the
16 formed graded junction regions are LDD regions.

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18 35. The method of claim 31 further comprising incorporating the
19 transistor gate into a PMOS transistor, wherein the implanted
20 conductivity-enhancing dopant is an n-type dopant, and wherein the
21 formed graded junction regions are halo regions.

1 36. The method of claim 31 further comprising incorporating the
2 transistor gate into an NMOS transistor, wherein the implanted
3 conductivity-enhancing dopant is a p-type dopant, and wherein the
4 formed graded junction regions are halo regions.

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6 37. The method of claim 31 further comprising incorporating the
7 transistor gate into an NMOS transistor, wherein the implanted
8 conductivity-enhancing dopant is an n-type dopant, and wherein the
9 formed graded junction regions are LDD regions.

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11 38. A transistor formed by the method of claim 31.
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1 39. A semiconductor transistor device comprising:
2 a region of a semiconductor material wafer;
3 a transistor gate over a portion of the region of the
4 semiconductor material wafer, the transistor gate having opposing lateral
5 sidewalls;
6 opposing source/drain regions operatively adjacent the transistor
7 gate, each source/drain region having an inner lateral boundary;
8 opposing sidewall spacers adjacent the sidewalls of the transistor
9 gate, each sidewall spacer having an outer lateral edge, the sidewall
10 spacers and source/drain regions being paired such that the outer lateral
11 edges of the sidewall spacers are displaced laterally inwardly relative to
12 the inner lateral boundaries of the source/drain regions; and
13 lateral gaps, the lateral gaps extending from the outer lateral
14 edges of the sidewall spacers to the inner lateral boundaries of the
15 source/drain regions.

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17 40. The device of claim 39 wherein the lateral gaps have a
18 length, the length of the lateral gaps being from about 200 Angstroms
19 to about 600 Angstroms.

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21 41. The device of claim 39 further comprising graded junction
22 regions inwardly adjacent the source/drain regions, the graded junction
23 regions extending within the lateral gaps.
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1 42. A method for forming a peripheral NMOS transistor and
2 one or more memory NMOS transistors, the method comprising the
3 following steps:

4 forming a peripheral NMOS transistor gate and one or more
5 memory NMOS transistor gates;

6 forming source/drain regions, halo regions and LDD regions
7 operatively adjacent the peripheral NMOS transistor gate, and forming
8 source/drain regions operatively adjacent the one or more memory
9 NMOS transistor gates, the steps of forming the regions occurring in a
10 sequence such that one or more of the regions are formed last and are
11 therefore last formed regions, wherein the LDD regions formed
12 operatively adjacent the peripheral NMOS transistor gate are not the
13 last formed regions; and

14 less than two masking layer provision steps after the formation of
15 the LDD regions operatively adjacent the peripheral NMOS transistor
16 gate, and prior to formation of the one or more last formed regions.

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18 43. A method for forming graded junction regions operatively
19 adjacent a transistor gate of CMOS circuitry, the method comprising the
20 following steps:

21 providing a semiconductor material wafer;

22 defining a PMOS region and an NMOS region of the wafer;

23 providing a gate layer over the PMOS region and over the NMOS
24 region;

1 patterning the gate layer over the NMOS region to form an
2 NMOS transistor gate over the NMOS region while leaving the gate
3 layer over the PMOS region unpatterned, the NMOS transistor gate
4 having opposing lateral sidewalls;

5 providing sidewall spacers adjacent the sidewalls of the NMOS
6 transistor gate, the sidewall spacers having a lateral thickness and
7 comprising a sidewall spacer material;

8 after providing the sidewall spacers, forming electrically conductive
9 NMOS source/drain regions within the semiconductor material operatively
10 adjacent the NMOS transistor gate;

11 after forming the electrically conductive NMOS source/drain
12 regions, etching the sidewall spacer material adjacent the NMOS
13 transistor gate to remove only a portion of said spacer material and to
14 thereby decrease the lateral thickness of the sidewall spacers; and

15 after decreasing the lateral thickness of the sidewall spacers
16 adjacent the NMOS transistor gate, implanting conductivity-enhancing
17 dopant into the semiconductor material to thereby form NMOS graded
18 junction regions operatively adjacent the NMOS source/drain regions.

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20 44. The method of claim 43 wherein the implanted conductivity-
21 enhancing dopant is a p-type dopant and wherein the formed NMOS
22 graded junction regions are halo regions.
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1 45. The method of claim 43 wherein the portion of spacer
2 material removed from the sidewall spacers constitutes no more than
3 about 90% of the lateral thickness of the sidewall spacers adjacent the
4 NMOS transistor gate.

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6 46. The method of claim 43 wherein the gate layer comprises
7 a polysilicon layer, a refractory metal layer over the polysilicon layer,
8 an oxide layer over the refractory metal layer, and a silicon nitride
9 layer over the oxide layer.

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11 47. The method of claim 43 further comprising, after forming
12 the NMOS transistor gate, and prior to providing sidewall spacers,
13 forming NMOS LDD regions operatively adjacent the NMOS transistor
14 gate.

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16 48. The method of claim 43 wherein the opposing lateral
17 sidewalls of the NMOS transistor gate comprise polysilicon, the method
18 further comprising:

19 prior to providing sidewall spacers adjacent the NMOS transistor
20 gate, oxidizing the polysilicon of the opposing lateral sidewalls to form
21 an oxide layer along each opposing lateral sidewall.

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1 49. The method of claim 48 further comprising, after forming
2 the NMOS transistor gate, and prior to providing the oxide layer along
3 each opposing lateral sidewall, forming NMOS LDD regions operatively
4 adjacent the NMOS transistor gate.
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6 50. The method of claim 43 wherein the semiconductor material
7 wafer comprises an overall planar global configuration, the planar global
8 configuration establishing a virtual planar top surface and an axis
9 normal to the virtual planar top surface, and wherein the p-type
10 conductivity-enhancing dopant is implanted at an angle other than
11 parallel to the axis normal to the virtual planar top surface.
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13 51. The method of claim 43 further comprising:
14 after forming the NMOS transistor gate, patterning the gate layer
15 over the PMOS region to form a PMOS transistor gate over the PMOS
16 region.
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1 52. A method for implanting graded junction regions into a
2 peripheral NMOS transistor and into a memory array of NMOS
3 transistors, the method comprising the following steps:

4 providing a semiconductor material wafer;

5 defining a memory array region, a PMOS region and a peripheral
6 NMOS region of the wafer;

7 providing a gate layer over the PMOS, peripheral NMOS and
8 memory array regions;

9 patterning the gate layer over the peripheral NMOS region to
10 form a peripheral NMOS transistor gate over the peripheral NMOS
11 region, the peripheral NMOS transistor gate having opposing lateral
12 sidewalls;

13 patterning the gate layer over the memory array region to form
14 an array of memory NMOS transistor gates over the memory array
15 region, the memory NMOS transistor gates having opposing lateral
16 sidewalls;

17 while patterning the gate layer over the peripheral NMOS region,
18 and while patterning the gate layer over the memory array region,
19 leaving the gate layer over the PMOS region unpatterned;

20 providing sidewall spacers adjacent the sidewalls of the peripheral
21 and memory NMOS transistor gates, the sidewall spacers having a
22 lateral thickness and comprising a sidewall spacer material;

1 after providing the sidewall spacers forming electrically conductive
2 peripheral NMOS source/drain regions within the semiconductor material
3 operatively adjacent the peripheral NMOS transistor gate;

4 after forming the electrically conductive NMOS source/drain
5 regions, etching the sidewall spacer material adjacent the peripheral
6 NMOS transistor gate to remove only a portion of said spacer material
7 and to thereby decrease the lateral thickness of the sidewall spacers
8 adjacent the peripheral NMOS transistor gate; and

9 after decreasing the lateral thickness of the sidewall spacers
10 adjacent the peripheral NMOS transistor gate, implanting conductivity-
11 enhancing dopant into the semiconductor material to form peripheral
12 NMOS graded junction regions operatively adjacent the peripheral NMOS
13 transistor gate.

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15 53. The method of claim 52 wherein the semiconductor material
16 wafer comprises an overall planar global configuration, the planar global
17 configuration establishing a virtual planar top surface and an axis
18 normal to the virtual planar top surface, and wherein the p-type
19 conductivity-enhancing dopant is implanted at an angle other than
20 parallel to the axis normal to the virtual planar top surface.

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22 54. The method of claim 52 wherein the implanted conductivity-
23 enhancing dopant is a p-type dopant and wherein the formed NMOS
24 graded junction regions are halo regions.

1 55. The method of claim 52 further comprising, after providing
2 sidewall spacers adjacent the sidewalls of the peripheral and memory
3 NMOS transistor gates, and prior to forming electrically-conductive
4 NMOS source/drain regions, providing a masking layer over the memory
5 array region.

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7 56. The method of claim 52 further comprising, after providing
8 transistor gates over the peripheral NMOS region and over the memory
9 array region, and prior to providing sidewall spacers adjacent the
10 sidewalls of the transistor gates, providing LDD regions operatively
11 adjacent the peripheral NMOS transistor gate and providing source/drain
12 regions operatively adjacent the memory NMOS transistor gates.

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14 57. The method of claim 52 wherein the opposing lateral
15 sidewalls of the peripheral and memory NMOS transistor gates comprise
16 polysilicon, the method further comprising:

17 prior to providing sidewall spacers adjacent the sidewalls of the
18 peripheral and memory NMOS transistor gates, oxidizing the polysilicon
19 of the opposing lateral sidewalls to form an oxide layer along each of
20 the opposing lateral sidewalls.

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22 58. The method of claim 57 further comprising, prior to
23 providing the oxide layer along each lateral sidewall of the peripheral
24 and memory NMOS transistor gates, forming peripheral NMOS LDD

1 regions operatively adjacent the peripheral NMOS transistor gate and
2 forming memory NMOS source/drain regions operatively adjacent the
3 memory NMOS transistor gates.

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5 59. The method of claim 52 further comprising:

6 after forming halo regions operatively adjacent the NMOS
7 source/drain regions, providing a masking layer over the peripheral
8 NMOS region;

9 after providing the masking layer over the peripheral NMOS
10 region, patterning a PMOS transistor gate over the PMOS region; and

11 forming electrically conductive PMOS source/drain regions
12 operatively adjacent the PMOS transistor gate.

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14 60. The method of claim 59 further comprising forming PMOS
15 graded junction regions operatively adjacent the PMOS source/drain
16 regions.

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18 61. The method of claim 59 further comprising forming PMOS
19 graded junction regions operatively adjacent the PMOS source/drain
20 regions, wherein the PMOS graded junction regions are formed after the
21 PMOS source/drain regions are formed.

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23 62. The method of claim 59 wherein the PMOS transistor gate
24 has opposing lateral sidewalls, and further comprising:

1 providing sidewall spacers adjacent the sidewalls of the PMOS
2 transistor gate, the sidewall spacers having a lateral thickness and
3 comprising a sidewall spacer material;

4 after forming the electrically conductive PMOS source/drain regions,
5 etching the sidewall spacer material adjacent the PMOS transistor gate
6 to remove only a portion of said spacer material and to thereby
7 decrease the lateral thickness of the sidewall spacers adjacent the PMOS
8 transistor gate; and

9 after decreasing the lateral thickness of the sidewall spacers
10 adjacent the PMOS transistor gate, implanting conductivity-enhancing
11 dopant into the semiconductor material of the PMOS region to form
12 PMOS graded junction regions operatively adjacent the PMOS transistor
13 gate.

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15 63. The method of claim 59 wherein the PMOS transistor gate
16 has a top and pair of opposing lateral sidewalls, and further comprising:

17 providing an overhanging PMOS capping layer over the top of the
18 PMOS transistor gate, the capping layer extending laterally outward
19 beyond the pair of opposing lateral sidewalls;

20 after providing the capping layer, implanting p-type conductivity-
21 enhancing dopant into the semiconductor material of the PMOS region
22 to form the electrically conductive source/drain regions operatively
23 adjacent the PMOS transistor gate, the overhanging capping layer
24 offsetting the PMOS source/drain regions from the PMOS transistor gate;

1 removing the overhanging capping layer from the top of the
2 PMOS transistor gate; and

3 implanting a conductivity-enhancing dopant into the semiconductor
4 material of the PMOS region to form PMOS graded junction regions
5 operatively adjacent the PMOS source/drain regions.

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64. A method for forming graded junction regions operatively adjacent a transistor gate, the method comprising the following steps:

providing a semiconductor material wafer;

providing a transistor gate over the semiconductor material wafer, the transistor gate comprising a layer of polysilicon and having opposing lateral sidewalls which include an exposed portion of the layer of polysilicon;

forming an oxide layer along the exposed portion of the layer of polysilicon of the lateral sidewalls;

providing sidewall spacers adjacent the sidewalls of the transistor gate and adjacent the oxide layer, the sidewall spacers having a lateral thickness and comprising a sidewall spacer material;

after providing the sidewall spacers, implanting a first conductivity-enhancing dopant into the semiconductor wafer to form electrically conductive source/drain regions within the semiconductor material operatively adjacent the transistor gate;

after forming the electrically conductive source/drain regions, etching the sidewall spacer material adjacent the transistor gate to remove said sidewall spacers and to thereby expose the oxide layer; and

after exposing the oxide layer, implanting a second conductivity-enhancing dopant into the semiconductor material to form graded junction regions operatively adjacent the transistor gate.

1 65. The method of claim 64 further comprising, prior to forming
2 the oxide layer along the exposed portion of the layer of polysilicon,
3 forming graded junction regions operatively adjacent the transistor gate.
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5 66. The method of claim 64 wherein the first conductivity-
6 enhancing dopant is p-type, the second conductivity-enhancing dopant is
7 n-type, and the implant of the second conductivity enhancing dopant
8 forms halo regions.
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10 67. The method of claim 64 wherein the first conductivity-
11 enhancing dopant is p-type, the second conductivity-enhancing dopant is
12 p-type, and the implant of the second conductivity enhancing dopant
13 forms LDD regions.
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15 68. The method of claim 64 wherein the first conductivity-
16 enhancing dopant is n-type, the second conductivity-enhancing dopant is
17 n-type, and the implant of the second conductivity enhancing dopant
18 forms LDD regions.
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20 69. The method of claim 64 wherein the first conductivity-
21 enhancing dopant is n-type, the second conductivity-enhancing dopant is
22 p-type, and the implant of the second conductivity enhancing dopant
23 forms halo regions.
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1 70. A method for forming a peripheral NMOS transistor and a
2 memory array of NMOS transistors, the method comprising the following
3 steps:

4 providing a semiconductor material wafer;

5 defining a memory array region, a PMOS region and a peripheral
6 NMOS region of the wafer;

7 providing a gate layer over the PMOS, peripheral NMOS and
8 memory array regions, the gate layer comprising a layer of polysilicon;

9 patterning the gate layer over the peripheral NMOS region to
10 form a peripheral NMOS transistor gate, the peripheral NMOS transistor
11 gate having opposing lateral sidewalls which include an exposed portion
12 of the layer of polysilicon;

13 patterning the gate layer over the memory array region to form
14 an array of memory NMOS transistor gates over the memory array
15 region, the memory NMOS transistor gates having opposing lateral
16 sidewalls which include an exposed portion of the layer of polysilicon;

17 while patterning the gate layer over the peripheral NMOS region,
18 and while patterning the gate layer over the memory array regions,
19 leaving the gate layer over the PMOS region unpatterned;

20 forming an oxide layer along the exposed portion of the layer of
21 polysilicon of the lateral sidewalls of the peripheral NMOS transistor
22 gate and along the exposed portions of the layer of polysilicon of the
23 lateral sidewalls of the memory NMOS transistor gates;

1 providing sidewall spacers adjacent the sidewalls of the peripheral
2 and memory NMOS transistor gates and adjacent the oxide layers;

3 after providing the sidewall spacers, forming electrically conductive
4 peripheral NMOS source/drain regions within the semiconductor material
5 operatively adjacent the peripheral NMOS transistor gate;

6 after forming the electrically conductive NMOS source/drain
7 regions, removing the sidewall spacers from adjacent the peripheral
8 NMOS transistor gate; and

9 after removing the sidewall spacers, implanting conductivity-
10 enhancing dopant into the semiconductor material to form peripheral
11 NMOS graded junction regions operatively adjacent the peripheral NMOS
12 transistor gate.

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14 71. The method of claim 70 further comprising, prior to forming
15 the oxide layer along the exposed portion of the layer of polysilicon of
16 the lateral sidewalls of the peripheral NMOS transistor gate and along
17 the exposed portions of the layer of polysilicon of the lateral sidewalls
18 of the memory NMOS transistor gates, providing peripheral NMOS LDD
19 regions operatively adjacent the peripheral NMOS transistor gate and
20 providing electrically-conductive memory array source/drain operatively
21 adjacent the memory array transistor gates.

1 72. The method of claim 70 wherein the implant of conductivity-
2 enhancing dopant into the semiconductor material comprises implanting
3 p-type conductivity enhancing dopant and thereby forms peripheral
4 NMOS halo regions operatively adjacent the peripheral NMOS transistor
5 gate.

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7 73. The method of claim 70 further comprising, prior to forming
8 the oxide layer along the exposed portion of the layer of polysilicon of
9 the lateral sidewalls of the peripheral NMOS transistor gate and along
10 the exposed portions of the layer of polysilicon of the lateral sidewalls
11 of the memory NMOS transistor gates, providing peripheral NMOS LDD
12 regions operatively adjacent the peripheral NMOS transistor gate and
13 providing electrically-conductive memory array source/drain operatively
14 adjacent the memory array transistor gates; and wherein the implant of
15 conductivity-enhancing dopant into the semiconductor material comprises
16 implanting p-type conductivity enhancing dopant and thereby forms
17 peripheral NMOS halo regions operatively adjacent the peripheral NMOS
18 transistor gate.

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20 74. The method of claim 70 further comprising, after providing
21 sidewall spacers adjacent the sidewalls of the peripheral and memory
22 NMOS transistor gates, and prior to forming electrically-conductive
23 NMOS source/drain regions, providing a masking layer over the memory
24 array region.

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75. The method of claim 70 further comprising:
after forming peripheral NMOS graded junction regions operatively
adjacent the NMOS source/drain regions, patterning a PMOS transistor
gate over the PMOS region.

1 76. A method for forming a transistor device, the method
2 comprising the following steps:

3 providing a semiconductor material wafer, the semiconductor wafer
4 having a surface;

5 providing a transistor gate layer atop the surface of the
6 semiconductor wafer, the transistor gate comprising an upper oxide layer
7 and an insulative cap layer over the upper oxide layer, the upper oxide
8 layer having an upper surface, the upper oxide upper surface being at
9 a level above the surface of the semiconductor wafer, the insulative cap
10 comprising an insulative cap material;

11 providing a masking layer over the transistor gate and over the
12 surface of the semiconductor substrate, the masking layer having an
13 upper surface and comprising a masking layer material;

14 removing masking layer material from over the transistor gate until
15 the masking layer upper surface is about level with the level of the
16 upper surface of the upper oxide layer; and

17 etching the insulative cap material to remove the insulative cap
18 from over the transistor gate to thereby expose the upper surface of
19 the upper oxide layer.

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21 77. The method of claim 76 wherein the masking layer material
22 comprises photoresist.
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1 78. The method of claim 76 wherein the insulative cap material
2 comprises silicon nitride.

3
4 79. The method of claim 76 wherein the transistor gate
5 comprises opposing lateral sidewalls, the method further comprising:

6 after forming the transistor gate, providing sidewall spacers
7 adjacent the opposing lateral sidewalls of the transistor gate, the
8 sidewalls having a top surface, the top surface of the sidewall spacers
9 being elevationally above the upper surface of the upper oxide layer;
10 and

11 etching the sidewall spacers to form flat top surfaces of the
12 sidewall spacers, the flat top surfaces being elevationally at about the
13 same level as the exposed upper surface of the upper oxide layer of
14 the transistor gate.
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1 80. The method of claim 76 wherein the transistor gate
2 comprises opposing lateral sidewalls, the method further comprising:

3 after forming the transistor gate, providing sidewall spacers
4 adjacent the opposing lateral sidewalls of the transistor gate, the
5 sidewalls having a top surface, the top surface of the sidewall spacers
6 being elevationally above the upper surface of the upper oxide layer,
7 the sidewall spacers comprising a sidewall spacer material which is
8 identical to the material of the insulative cap; and

9 etching the sidewall spacer material to form flat top surfaces of
10 the sidewall spacers, the flat top surfaces being elevationally at about
11 the same level as the exposed upper surface of the upper oxide layer
12 of the transistor gate, the etching of the sidewall spacer material
13 occurring concurrently with the etching of the insulative cap material.
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15 81. The method of claim 80 wherein the insulative cap material
16 and the sidewall spacer material both comprise silicon nitride.
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1 82. A method for forming CMOS circuitry, the method
2 comprising the following steps:

3 providing a semiconductor material wafer, the semiconductor wafer
4 having a surface;

5 defining a PMOS region and an NMOS region of the wafer;

6 providing a gate layer over the PMOS region and over the NMOS
7 region, the gate layer having an upper oxide layer and an insulative cap
8 over the upper oxide layer, the upper oxide layer having an upper
9 surface, the upper oxide upper surface being at a level above the
10 surface of the semiconductor wafer, the insulative cap comprising an
11 insulative cap material;

12 patterning the gate layer over the NMOS region to form an
13 NMOS transistor gate over the NMOS region while leaving the gate
14 layer over the PMOS region unpatterned;

15 providing a masking layer over the PMOS region and the NMOS
16 region, the masking layer having an upper surface and comprising a
17 masking layer material;

18 removing masking layer material from over the PMOS and NMOS
19 regions until the masking layer upper surface is about level with the
20 level of the upper surface of the upper oxide layer; and

21 etching the insulative cap material to remove the insulative cap
22 from over the NMOS gate and from over the unpatterned gate layer
23 over the PMOS region to thereby expose the upper surface of the
24 upper oxide layer of the NMOS gate and to also thereby expose the

1 upper surface of the upper oxide layer of the unpatterned gate layer
2 over the PMOS region.
3

4 83. The method of claim 82 wherein the masking layer material
5 comprises photoresist.
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7 84. The method of claim 82 wherein the insulative cap material
8 comprises silicon nitride.
9

10 85. The method of claim 82 wherein the NMOS transistor gate
11 comprises opposing lateral sidewalls, the method further comprising:

12 after forming the NMOS transistor gate, providing sidewall spacers
13 adjacent the opposing lateral sidewalls of the NMOS transistor gate, the
14 sidewalls having a top surface, the top surface of the sidewall spacers
15 being elevationally above the upper surface of the upper oxide layer;
16 and

17 etching the sidewall spacers to form flat top surfaces of the
18 sidewall spacers, the flat top surfaces being elevationally at about the
19 same level as the exposed upper surface of the upper oxide layer of
20 the NMOS gate.
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1 86. The method of claim 82 wherein the NMOS transistor gate
2 comprises opposing lateral sidewalls, the method further comprising:

3 after forming the NMOS transistor gate, providing sidewall spacers
4 adjacent the opposing lateral sidewalls of the NMOS transistor gate, the
5 sidewalls having a top surface, the top surface of the sidewall spacers
6 being elevationally above the upper surface of the upper oxide layer,
7 the sidewall spacers comprising a sidewall spacer material which is
8 identical to the material of the insulative cap; and

9 etching the sidewall spacer material to form flat top surfaces of
10 the sidewall spacers, the flat top surfaces being elevationally at about
11 the same level as the exposed upper surface of the upper oxide layer
12 of the NMOS gate, the etching of the sidewall spacer material occurring
13 concurrently with the etching of the insulative cap material.

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15 87. The method of claim 86 wherein the insulative cap material
16 and the sidewall spacer material both comprise silicon nitride.

1 88. A method for forming an NMOS transistor device and an
2 insulated word line, the method comprising the following steps:

3 providing a semiconductor material wafer, the semiconductor wafer
4 having a surface;

5 defining a memory array region of the wafer and a peripheral
6 NMOS region of the wafer;

7 providing a gate layer over the peripheral NMOS and memory
8 array regions of the wafer, the gate layer having an upper oxide layer
9 and an insulative cap over the upper oxide layer, the upper oxide layer
10 having an upper surface, the upper oxide layer upper surface being at
11 a level above the surface of the semiconductor wafer, the insulative cap
12 comprising an insulative cap material;

13 patterning the gate layer over the peripheral NMOS region to
14 form a peripheral NMOS transistor gate over the peripheral NMOS
15 region, the peripheral NMOS transistor gate having opposing lateral
16 sidewalls;

17 patterning the gate layer over the memory array region to form
18 a word line, the word line having opposing lateral sidewalls;

19 providing insulative sidewall spacers adjacent the opposing lateral
20 sidewalls of the peripheral NMOS transistor gate and adjacent the
21 opposing lateral sidewalls of the word line, the sidewall spacers
22 comprising a sidewall spacer material;

1 providing a masking layer over the peripheral NMOS region, the
2 masking layer having an upper surface and comprising a masking layer
3 material;

4 removing the masking layer material from over peripheral NMOS
5 region until the masking layer upper surface is about level with the
6 upper oxide layer upper surface; and

7 removing the insulative cap material from over the peripheral
8 NMOS transistor gate to expose the upper oxide upper surface of the
9 peripheral NMOS gate.

10
11 89. The method of claim 88 further comprising:

12 prior to removing the masking layer material from over the
13 peripheral NMOS transistor gate, providing a masking layer over the
14 word line, the masking layer over the word line comprising a masking
15 layer material identical to the masking material of the masking layer
16 over the peripheral NMOS transistor gate, the masking layer material
17 over the word line having an upper surface which is elevationally above
18 the upper surface of the masking material over the peripheral NMOS
19 transistor gate; and

20 wherein the step of removing the masking layer material from
21 over peripheral NMOS region leaves masking layer material over the
22 word line.
23
24

1 90. The method of claim 88 further comprising:
2 prior to removing the insulative cap from over the peripheral
3 NMOS transistor gate, providing a masking layer over the word line.
4

5 91. The method of claim 88 further comprising:
6 defining a PMOS region of the semiconductor material wafer;
7 providing the gate layer over the PMOS region;
8 while patterning the gate layer over the peripheral NMOS region,
9 and while patterning the gate layer over the memory array region,
10 leaving the gate layer over the PMOS region unpatterned; and
11 while providing the masking layer over the peripheral NMOS
12 region, also providing the masking layer over the PMOS region.
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1 92. The method of claim 88 further comprising:
2 defining a PMOS region of the semiconductor material wafer;
3 providing the gate layer over the PMOS region;
4 while patterning the gate layer over the peripheral NMOS region,
5 and while patterning the gate layer over the memory array region,
6 leaving the gate layer over the PMOS region unpatterned;
7 while providing the masking layer over the peripheral NMOS
8 region, also providing the masking layer over the PMOS region;
9 wherein the step of removing the masking layer material from
10 over peripheral NMOS region also removes masking layer material from
11 over the PMOS region; and
12 wherein the step of removing the insulative cap material from
13 over the peripheral NMOS transistor gate to expose the upper oxide
14 upper surface of the peripheral NMOS gate also removes insulative cap
15 material from over the PMOS region to expose an upper oxide surface
16 of the unpatterned masking material over the PMOS region.

1 93. The method of claim 88 wherein the sidewall spacers of the
2 peripheral NMOS transistor have a top surface, the top surfaces of the
3 sidewall spacers being elevationally above the upper surface of the
4 upper oxide layer of the peripheral NMOS transistor, the method
5 further comprising:

6 etching the sidewall spacers of the peripheral NMOS transistor to
7 form flat top surfaces of the sidewall spacers of the peripheral NMOS
8 transistor, the flat top surfaces being elevationally at about the same
9 level as the exposed upper surface of the upper oxide layer of the
10 peripheral NMOS gate.
11

12 94. The method of claim 88 wherein the sidewall spacers of the
13 peripheral NMOS transistor have a top surface, the top surfaces of the
14 sidewall spacers being elevationally above the upper surface of the
15 upper oxide layer of the peripheral NMOS transistor, the method
16 further comprising:

17 etching the sidewall spacer material of the peripheral NMOS
18 transistor to form flat top surfaces of the sidewall spacers of the
19 peripheral NMOS transistor, the flat top surfaces being elevationally at
20 about the same level as the exposed upper surface of the upper oxide
21 layer of the peripheral NMOS gate, the etching of the sidewall spacer
22 material occurring concurrently with the etching of the insulative cap
23 material.
24

1 95. The method of claim 88 further comprising patterning the
2 gate layer over the memory array region to form memory transistor
3 gates.

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5 96. The method of claim 88 wherein the insulative cap material
6 and the sidewall spacer material both comprise silicon nitride.

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1 97. A method for forming a PMOS transistor device, a
2 peripheral NMOS transistor device, and one or more memory NMOS
3 transistor devices, the method comprising the following steps:

4 providing a semiconductor material wafer;

5 defining a PMOS region, a peripheral NMOS region, and a
6 memory array region of the wafer;

7 providing a gate layer over the PMOS, peripheral NMOS and
8 memory array regions;

9 patterning the gate layer over the peripheral NMOS region to
10 form a peripheral NMOS transistor gate;

11 patterning the gate layer over the memory array region to form
12 one or more memory array transistor gates;

13 while patterning the gate layer over the peripheral NMOS and
14 memory array regions, leaving the gate layer over the PMOS region
15 unpatterned;

16 forming source/drain regions, halo regions and LDD regions
17 operatively adjacent the peripheral NMOS transistor gate, and forming
18 source/drain regions operatively adjacent the one or more memory
19 NMOS transistor gates, the steps of forming the regions occurring in a
20 sequence such that one or more of the regions are formed last and are
21 therefore last formed regions; and

22 less than two masking layer provision steps after the formation of
23 the peripheral NMOS transistor gate, and prior to the formation of the
24 one or more last formed regions.

1 98. A method of forming a transistor structure on a
2 semiconductor substrate, comprising the following steps:

3 providing a transistor gate assembly formed on said substrate, said
4 gate assembly including sidewall spacers extending to said substrate;

5 doping a first region of said substrate with a selected dopant;

6 removing a lateral portion of at least one of said sidewall spacers,
7 while leaving a part of said at least one of said sidewall spacers in
8 place; and

9 after said removal, doping a second portion of said substrate.
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